

Chemical Purchasing Practices

General Description:

Chemical purchasing practices and inventory control have been identified by the American Chemical Society as prime opportunities for reducing waste generation in the laboratory. Obsolete and expired chemicals can contribute significantly to a laboratories waste stream. By reviewing your purchasing and inventory control practices your business may find pollution prevention opportunities that will reduce chemical hazards, waste chemicals and disposal costs.

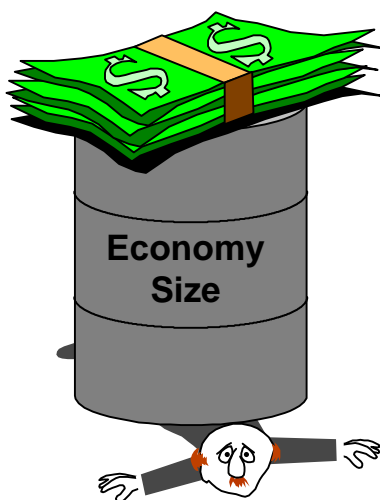
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LESS IS BEST



There are many reasons for smaller purchases

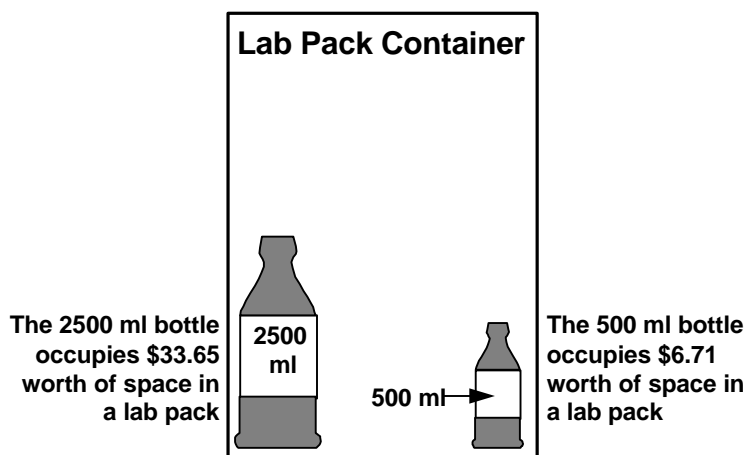
- Material taken from large "Economy Size" containers can be twice as costly as material taken from smaller packages.
- Disposal costs per package can be up to 25% less for smaller containers than large containers.
- Smaller containers are emptied faster and there is less chance of chemical decomposition when using smaller containers.
- Accident risk and exposure to hazardous materials is reduced when handling small containers.
- Business liability and paperwork is reduced due to the reduction of materials being disposed. Records of all materials sent to disposal must be on file for at least three years, although the general recommendation is to maintain these records for the life of the business.
- Higher costs are associated with the handling and storage of larger containers. Additional stockroom planning and design is needed to prevent and control fires, increase ventilation, and reduce accidental spills and chemical reactions.
- Larger containers often require additional equipment such as smaller transfer containers, funnels, pumps, and labels.
- Additional labor is needed to subdivide larger containers into smaller containers.
- Additional personal protective equipment may also be necessary.



<div>  Purchasing-Disposal Economics <i>(in 1993 dollars)</i>  </div>		
	Size of package	
	500 ml	2500 ml
Purchase Price	\$25.00	\$65.00
Unit Purchase Price per milliliter	0.05	0.03
When 1000 ml are used		
Price per milliliter (purchase price ÷ 1000 ml)	0.05	0.07
Estimated Bottle Disposal Cost	0.00	33.65
Total Cost (purchase & disposal)	50.00	98.65
Total Cost per milliliter (Total Cost ÷ 1000 ml)	0.05	0.10
When 1300 ml are used		
Price per milliliter (purchase price ÷ 1300 ml)	0.05	0.05
Estimated Bottle Disposal Cost	6.73	33.65
Total Cost (purchase & disposal)	81.73	98.65
Total Cost per milliliter (Total Cost ÷ 1300 ml)	0.06	0.08

(from: "Less is Better: Laboratory Chemical Management for Waste Reduction," 2nd Ed., American Chemical Society Task Force on Laboratory Waste Management, ACS, 1993)

A 2500 ml bottle occupies approximately \$33.65 worth of space in a lab pack, a 500 ml bottle occupies approximately \$6.71 of space in a lab pack (a typical 55 gallon lab pack can hold appx. fifty-two 500 ml bottles). No matter how much chemical is used (unless the bottle is emptied) the container will always cost this amount since a bottle will take up the physical space in the lab pack container.



Unless your lab

uses all the

chemical in an "Economy Size" container disposal costs will often outweigh bulk material savings.

Formaldehyde

General Description

The hazards associated with formaldehyde and formalin solutions are well defined. OSHA has adopted the Formaldehyde Standard to protect workers from formaldehyde. Disposal of formaldehyde as a waste material is not as clearly defined and no uniform standard exists. Some wastewater treatment plants ban the disposal of formaldehyde to their systems while others allow it to be sewerred. Formaldehyde is a toxic chemical that potentially could harm microbial processes used in wastewater treatment systems.

The allowable formaldehyde limit that facilities are subject to is listed in Albuquerque's Sewer Use and Wastewater Control Ordinance. The limit is 100 parts per million (mg/l). Ten percent formalin contains 3.7% formaldehyde or 37,000 parts per million (ppm) of formaldehyde. Disposal of formalin to the sewer even with downstream dilution is discouraged in favor of pollution prevention practices that will minimize toxic chemicals. Pollution prevention (p2) practices such as product substitutions, source reduction and recycling are used to reduce sewer discharge of toxic chemicals such as formaldehyde.

Concentrated aqueous solutions of formaldehyde are sold in concentrations ranging from 37% to 50% formaldehyde. 10% formalin is made by a 10 to 1 dilution with water using 37% formaldehyde solution. Pure formaldehyde is not commercially available because of it's tendency to polymerize. Other additives to formalin are methanol, zinc and phosphates for buffered solutions. The molecular formula of formaldehyde is CH₂O.

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Waste Material Identification

Determining the composition of commercial formaldehyde formulations should be based on referring first to the MSDS sheets from the supplier(s). Formulations of formaldehyde vary with different additives. Common additives are methanol, zinc and phosphates.

Hazardous or non-hazardous?

1. Container residues, spill residues, and discarded formaldehyde product are a listed hazardous waste (EPA Waste # U122).

Other characteristics of formaldehyde that might make it a hazardous waste are its ignitability (flash point less than 140 degrees Fahrenheit) its corrosiveness, and cross contamination with mercury from specimens treated with mercuric fixatives.

Required Action: Handle this waste as a hazardous waste observing all hazardous waste regulations.

REMEMBER: One Pound of Hazardous Waste + 49 Pounds of Nonhazardous Wastes = 50 Pounds of Hazardous Waste

The hierarchy of waste management alternatives for formalin is as follows:

- Source Reduction: minimize volume of formalin used
- Material Substitution: use non-formalin substitutes and non-mercuric fixatives
- On-Site Recycling: use an on-site distillation unit to recycle waste formaldehyde or formaldehyde substitutes to a reusable product
- Treatment: treat formalin to detoxify it before sewerage
- Storage and Disposal: use the services of an EPA licensed hazardous waste disposal company

Formaldehyde Substitutes

Formaldehyde substitutes are commercially available from several companies listed in the table below. A careful review of the ingredients chemical safety and disposal is necessary when reviewing alternatives to formaldehyde. Attention to FDA regulations on labeling of chemicals acceptable for diagnostic purposes is needed when selecting substitutes.

Table 1 - Formaldehyde Substitutes

Product Name	Supplier	Phone Number
HistoFix	Trend Scientific, Inc. P.O. Box 120266 St. Paul, MN 55112	1-800-328-3949
<i>Prefer</i>	ANATECH, LTD. 1020 Harts Lake Road Battle Creek, MI 49015	1-800-ANATECH
S.T.F.	Streck Laboratories, Inc. 14306 Industrial Road Omaha, NE 68144	1-800-228-6090

Conducting A Clinical Trial: (excerpt from Dapson, 1995, p.130)

- Use only fresh tissue, fixing as soon after removal from the patient as possible. Do not use autopsy material, as it will already show signs of autolysis.
- Gross specimens properly (no thicker than 4.5 mm; 5 mm is too thick for modern plastic cassette).
- Use enough fixative to provide a 20:1 ratio of fixative volume to specimen volume.
- Change all fixatives 2-3 times during the fixation period.
- Do not use tissue previously exposed to another fixative. You will not be able to tell which fixative was responsible for any good or bad effects.
- Run parallel studies with your current fixative. Divide the specimen into portions, one of which should be placed in each fixative. Allow 6-8 hours of fixation for each fixative (4-6 hours for biopsies). If your current fixative is B-5, continue using that for the normal time, but follow the above fixation periods for any non-mercuric substitute.
- Put all trial specimens into the first alcohol station of your processor. Do not post-fix in your current fixative.
- Continue processing as you normally would. Cut several slides from each block.
- Stain one set of slides (one from each fixative) together at your usual staining times. If any slides are too light or dark, customize your staining program to produce more

acceptable results on the remaining slides.

- Present the slides to your pathologist as a blind trial; that is, encode the slides so that the reviewer does not know the identity of the fixative.

Picric Acid in Fixatives

Picric acid is explosive when dry, shocked or heated or comes into contact with metals or metallic salts. It is toxic by skin absorption and its use should be avoided as much as possible. A metal-capped container of picric acid should not be opened due to reactivity hazards. If picric acid is dry do not attempt to handle the container. A professional hazardous materials response team should be called. Picric acid solutions should never be heated or microwaved. Solutions of picric acid should not be mixed with mercury or zinc salts. Leaching picric acid from specimens into a processor may pose an explosion hazard if metal picrates are formed (Dapson, 1995, p. 210).

Picric acid is used in fixatives such as Bouin's fixative. The mercuric fixative substitutes (Table 2, Mercury section) will provide comparable results if properly. For quicker penetration, alcoholic fixative versions are also available ((Dapson, 1995, p. 132).

Process Changes

Waste reduction changes by reducing the amount of fixative used in specimen containers should be carefully reviewed before implementing this practice. Some laboratories have found it feasible to reduce the volume of formaldehyde used in specimen containers (see Case Studies - Appendix G). The following guidelines and warnings are given (Dapson, 1996):

The customarily recommended ratio of fluid volume to specimen volume is 20:1. I'm not sure how critical that number is, but I do know that if the ratio gets much below 10:1, the quality of the specimen deteriorates severely. If we assumed that a specimen is essentially all water (it is >95%), and we put it into a volume of fixative equal to the volume of the specimen, we have diluted the fixative 1:1, that is, 10% formalin becomes 5% formalin. Putting a specimen into twice the volume of fixative would dilute the fixative to about 7% formalin. So, even before fixation has begun, the fixative has been seriously compromised.

Reusing the fixative compounds the problem. Each time formalin is used, some of the formaldehyde is removed from the solution as it combines with the specimen. Single-use formalin from labs employing reasonable fluid/tissue volume ratios frequently assays at about 8-9% (down from 10%). This is a 10-20% loss of formaldehyde, and it occurs in situations where the dilution effect described earlier is insignificant.

Why is concentration important? The rate of penetration (diffusion) and the rate of chemical reactivity are both dependent upon concentration of the fixative. In situations where fixative is being reused or reduced in volume (and hence diluted), we often see poor to catastrophically bad preservation. Diagnoses are sometimes impossible, and the patient must be subjected to another biopsy procedure. In some cases, the total pathological specimen has been taken, and now destroyed, with no

chance to get a replacement specimen.

There are medical liability issues here, to say nothing of violation of quality standards mandated by government regulations (CLIA '88) and laboratory accrediting agencies (e.g., CAP). Without careful measurement of the active ingredients of the fixative, volume reduction and repeated reuse are risky practices.

Formaldehyde Recycling

Distillation for recovery of solvents is a widespread practice for successful recovery of many different types of solvents. Distillation is currently safely being used in laboratories to recover formaldehyde. Refer to the section on distillation for more information about recycling formalin and its substitutes. Single use of reagents is expensive and produces more waste than reusing reagents. Disposal of formaldehyde as a hazardous waste is an expensive option (as much as \$9 per gallon for hazardous waste disposal) and pouring it down the drain violates the City's sewer use ordinance. Recycling may lower a lab's hazardous waste generator status thereby decreasing your record keeping requirements and hazardous waste fees.

Waste formaldehyde can be recycled using commercially available distillation units. Formaldehyde is placed into a distillation flask which is then heated. The formaldehyde and water boil off and the vapors are condensed in a separate container. The solids such as tissue, blood, and salts remain behind in the distillation flask. Some manufacturers provide a filter prior to distillation to remove solids. The distilled mixture contains water and formaldehyde minus any salts in the original waste material. There are kits available to add the salts such as zinc and phosphate salts to return the formaldehyde to its original composition.

The concentration of the distilled formalin solution may be different after distillation. Water or concentrated formaldehyde (37%) can be added to readjust to the desired formalin strength. There are kits available to test the formaldehyde concentration.

Advantages of Recycling Formaldehyde

A high recovery rate. Commercially available simple distillation units recover about 80% formaldehyde. Only about 20% waste remains after distillation.

Save money for your laboratory. Don't throw your money down the drain. Depending on how much formaldehyde your lab uses it may save your laboratory money in the long run. Refer to the worksheet on financial analysis.

Reduce your financial and legal burdens. Disposal of 10% formalin to the sewer system exceeds the City's Sewer Use and Wastewater Control Ordinance for formaldehyde. The proper disposal of formaldehyde waste requires disposing of it as a hazardous waste which is a costly service. By recycling formaldehyde you reduce formaldehyde waste and liabilities associated with disposal either to the sewer or through the services of a waste hauler.

Zinc formalin and phosphate buffered formalin can also be recycled. When zinc and phosphate buffered formalin is distilled it will lose the salts which will need to be added after distillation. Zinc and phosphate reconstitution kits are available or you can use your own chemical supplies. Test kits for formaldehyde are also available to determine the content of formaldehyde.

You can have a constant supply of formaldehyde and inventory can be reduced.

Disadvantages of Recycling Formaldehyde

Initial investment needed for a distillation unit.

Alcoholic formalin is generally not recycled because of the formaldehyde and alcohol mixture. Testing for alcohol content after recycling makes it difficult to adjust the alcohol content after the distillation. Alcohol may also pose a flammability problem for some formaldehyde distillation equipment.

Table 2 - Formaldehyde Recycling Equipment & Supplies

Product	Supplier	Phone Number
Distillation unit	B/R Instrument Corp. 9119 Centreville Rd. Easton, Maryland 21601	1-800-922-9206
Distillation unit	Shandon Lipshaw 171 Industry Drive Pittsburgh, PA 15275	1-800-547-7429
Assay and salt kits for recycled formaldehyde	ANATECH, LTD. 1020 Harts Lake Road Battle Creek, MI 49015	1-800-ANATECH

Chemical Treatment

General Description

The purpose of formaldehyde treatment is to convert formaldehyde into products that can be safely sewered or to remediate a spill. Chemical treatment of formaldehyde involves complex chemical reactions depending on the chemicals used for treatment. There are a number of available commercial products for formaldehyde destruction and they vary in their mode of treatment (see Table 3 below). The cost of chemical treatment of formaldehyde is estimated between \$7.00 to \$10.00 per gallon making it comparable to the cost of disposing of formaldehyde by hazardous waste disposal company.

The main categories of chemical treatment can be classified into the following three : 1.) chemical destruction 2.) polymerization 3.) fixation (Dapson, 1995, p. 165).

1.) Chemical destruction: Formaldehyde can be chemically destroyed to produce nonhazardous reaction products. In contrast to the other methods, this is the only one that actually destroys the

formaldehyde. Polymerization and fixation tie up the formaldehyde molecule but do not destroy it.

2.) Polymerization reactions. With polymerization the formaldehyde molecule is chemically tied up with another molecule in the presence of a catalyst. One method of polymerization is with urea in the presence of either an acid or an alkali at room temperature. The polymerization reactions may be reversible resulting in the original formaldehyde depending on which catalyst is used. Acid catalysts are essentially irreversible and produce a urea formaldehyde polymer. Alkali catalysts in the presence of urea and formaldehyde produce methylol formaldehyde polymers. These are reversible back to formaldehyde and urea which introduces nitrogen in the form of urea to the POTW. Other polymerization reactions include the use of polyaziridine.

3.) Fixation and physical adsorption. Formaldehyde will attach loosely to hydroxyl, sulfhydryl and amino groups but the reaction may be reversible. Formaldehyde can be physically fixated with adsorption onto granules of polyhydroxylated resin. Questions on the leachability of the formaldehyde from the adsorption material should be raised. Disposal of this material to the landfill may not be acceptable nor should it be sewered since it is a solid.

Keep the following considerations and questions in mind when choosing a formaldehyde detoxification product:

- Be sure to ask for a product MSDS sheet and an MSDS sheet should preferably be available for the reaction products.
- Information on the reaction products should be known in order to safely dispose of them.
- Data on the efficiency of the destruction reaction should be available from the vendor or a suitable test kit with known sensitivity should be purchased.
- Directions for use should include required reaction time and volumes.
- Be careful with products that produce solids such as a gelatin. Solids should not be poured down the sewer because they can clog sewer lines.

Table 3 - Formaldehyde Detoxification Products

Product Name	Supplier	Phone Number
FORMALDETOX	ANATECH, LTD. 1020 Harts Lake Road Battle Creek, MI 49015	1-800-ANATECH
DeToX	Earth Safe Industries Inc. Belle Meade, NJ	(908) 281-0522
VYTAC	Trend Scientific, Inc. St. Paul, MN	1-800-328-3949

Formaldehyde Disposal

Disposal costs using the services of a licensed waste hauler are high varying from about \$150 to \$500 per 55 gallon drum (\$2.73 to \$9.09 per gallon). Disposal is the least preferred option and carries the greatest amount of liability to the generator of the waste. Waste reduction and recycling of formaldehyde are the preferred options. The “cradle to grave” ownership that the EPA assigns to waste is a constant liability to companies that dispose of waste. The disposal of formaldehyde to a landfill is generally not allowable. Formaldehyde waste (EPA # U122) is banned from disposal to a landfill with few exceptions by EPA’s Land Ban Disposal regulations. Destruction of formaldehyde in an incinerator should only be done at an EPA-approved facility. Formalin solutions are mostly water, therefore they carry a low value as a fuel and this can increase the cost of incineration.

Ten percent formalin solutions contain approximately 3.7% or 37,000 milligrams per liter (parts per million) of formaldehyde. The City of Albuquerque’s Sewer Use and Wastewater Control Ordinance maximum discharge limit for formaldehyde is 100 ppm. Disposal of formaldehyde to the sewer should be considered a last resort. Disposal of small quantities of formaldehyde may be sufficiently diluted downstream within your facility to not exceed the discharge requirements at the point of sampling. However, there are alternatives available to reduce environmental liability.

Xylene and Clearants

General Description

Xylene is used in hematology, pathology and histology as a clearing agent, extractor, solvent for slide cleaning and other applications. Most laboratory workers are familiar with xylene's toxic and flammable material properties. Xylene use should be minimized whenever possible, recycled, or properly disposed of due to its hazardous nature properties. Careful attention is required in the handling, storage, and disposal of xylene. There are several excellent pollution prevention opportunities for laboratories that utilize xylene.

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Waste Material Identification

The first place to look when collecting information about the hazardous waste status of xylene and xylene substitutes is the Material Safety Data Sheets (MSDS). The composition of commercial clearant formulations should be listed on the MSDS. Xylene typically contains the different xylene isomers (m, o, and p-xylene) and ethyl benzene. The MSDS sheet will list the chemicals present prior to use of the clearant. The actual product as a waste material may contain water, alcohol, fat, tissue particles, and other contaminants that may have been introduced into the clearant.

Hazardous or non-hazardous? - Hazardous. Due to:

1. Xylene, limonene, and short-chain aliphatic hydrocarbons generally have flash points below 140 degrees Fahrenheit making them an ignitable hazardous waste. The EPA hazardous waste number for ignitable wastes is D001.
2. Xylene from spills, residues, and unused product is a listed EPA hazardous waste. The EPA's hazardous waste number for xylene is U239 and it falls under the category of listed toxic waste.

Required Action: Handle xylene and most xylene substitutes as hazardous waste observing all hazardous waste regulations.

REMEMBER: One Pound of Hazardous Waste + 49 Pounds of Nonhazardous Wastes = 50 Pounds of Hazardous Waste

The hierarchy of waste management alternatives for xylene and xylene substitutes are the following:

- Source Reduction: minimize volume of clearants used as much as possible
- Material Substitution: use non-xylene substitutes that are less toxic and recyclable
- On-Site Recycling: use an on-site distillation unit to recycle waste xylene and xylene substitutes
- Burn as a fuel supplement in an on-site furnace or use an EPA licensed hazardous waste disposal company

Xylene Substitutes

Because xylene is toxic and highly flammable, substitutes have been developed for use as clearants in biomedical applications. The advantage of substituting xylene is to replace it with a clearant that is less toxic and dangerous to work with and preferably with a substitute that can also be recycled and reused many times. A guide in considering substitutes to be used in diagnostic work is to look for those that are FDA approved and are labeled “for in vitro diagnostic use”. There are several categories of xylene substitutes based on their chemical components (Dapson, 1995, pp. 134-136):

1.) Limonene/terpene based clearants

In about 1980 limonene clearants became commercially marketed (from Dapson, 1995, p. 134). Limonene is a terpene compound derived from citrus peels. Limonene has a characteristic citrus odor. There are two forms of limonene commercially available and these are d-limonene and dl-limonene (dipentene). Limonene is volatile and has a flashpoint below 140 degrees Fahrenheit making it an ignitable waste. Limonene is insoluble in water.

Advantages:

Limonene is less toxic than xylene. Limonene is generally considered combustible (flash point exceeds 100 F) whereas xylene is flammable (flash point less than 100 F).

Disadvantages:

Limonene is a sensitizer which can cause long term allergic responses in laboratory workers. Allergic responses include difficult breathing, tightness in the chest, and possibly life-threatening anaphylaxis.

There are problems with recycling limonene due to the additives in limonene clearants. Additives to limonene include mineral and corn oils added to dilute the strong citrus odor of limonene. Anti-oxidants are also added to limonene. If the attempt is made to distill limonene for recycling, the additives are not distilled and the distilled limonene will not have the same characteristics as the original product.

A less common problem encountered when recycling limonene is thickening of the limonene solution. Limonene has a tendency to polymerize.

2.) Short-chain and long-chain aliphatic hydrocarbons

Aliphatic hydrocarbons are also known as alkanes. These are compounds that have only carbon and hydrogen atoms attached with single chemical bonds. The simplest aliphatic hydrocarbons are referred to as short-chain (i.e. methane). Increasing the length of the molecular structure leads to a long-chain of carbons and hydrogens which typically makes the compound less volatile and increases the flash point. Flash points can be used to differentiate between the short chain and long chain aliphatic hydrocarbons. The short-chain aliphatics have a flash point below 110 Fahrenheit. The long-chain ones have flash points over 140 F.

Advantages

The aliphatic hydrocarbons are almost odorless, non-irritating and non-sensitizing.

Short chain aliphatics will penetrate tissues quicker thereby removing fat more effectively. Coverslips can be allowed to dry in normal fashion.

Disadvantages

There is varying degree of intolerance for water depending on the manufacturer. Directions need to be followed with care given to coverslipping and in selection of mounting media

3.) Others

Other types of xylene substitutes may contain hydrocarbon blends, distillates , high boiling point aromatic hydrocarbons mixtures, and mineral oil mixtures. The advantages and disadvantages of these will vary depending on the chemicals involved. Caution should be taken in considering these because some of these may be just as toxic as xylene.

Table 1 - Suppliers of Short-Chain Aliphatic Hydrocarbon Clearants

Product	Supplier	Phone Number
PRO-PAR CLEARANT	ANATECH 1020 Harts Lake Road Battle Creek, MI 49015	1-800-ANATECH
Clear-Rite 3	Richard-Allan Scientific 225 Parsons Kalamazoo, MI 49007	1-800-253-7900
Shandon Xylene Substitute	Shandon Lipshaw 171 Industry Drive Pittsburgh, PA 15275	1-800-245-6212
Clearing Solvent 100	Stephens Scientific 107 Riverdale Rd. Riverdale, NJ 07457	1-800-831-8099

Xylene Recycling

Xylene can be recycled insuring a steady supply of xylene. Only new product needs to be bought to replenish any xylene lost to processes or distillation bottoms. Xylene recycling is becoming more widespread due to the relative ease of recycling xylene. Safe stills and the quality of xylene waste from histopathology laboratories has made xylene recycling popular. There are commercial stills available with built-in safeguards which automatically shut down the machine in case of overheating (Reinhardt, 1996 p. 104).

Xylene after the histopathology processes may be contaminated with water, tissue fat, particles, and/or alcohol. These impurities must be removed in order to reuse xylene. A survey carried out by a manufacturer of commercial stills found that from a survey of over 200 hospital laboratories the alcohol contamination rate varied widely from 0.6% to 64% alcohol. The average alcohol contamination concentration of the xylene was found to be about 15%. The manufacturer of the stills found that excellent quality xylene was recovered in high yield in all cases using the manufacturers' 8300 or 8400 distillation unit (Reinhardt, 1996 p. 341).

For more information about distillation please refer to the distillation section in the reference materials of this Code.

Xylene Substitutes Recycling

It is recommended that only short chain aliphatic hydrocarbons be recycled. The limonene based substitutes will not be the same after recycling since the oils and antioxidants that are added will not distill. Limonene will also tends to thicken as it is oxidized. The long chain hydrocarbons have boiling points that may not be safe for most distillation units (Dapson, 1995 p. 143).

Disposal

Recycling and reuse of clearants is the top pollution prevention option before disposal which is the least preferred method of waste management. Laboratories that dispose of their clearants increase their disposal costs, material purchasing expenses and their environmental liability. Disposal routes used by laboratories are disposal to the sewer system and off-site disposal. Off-site disposal should always involve using the services of a licensed hazardous waste hauler.

Sewer Disposal: The decision to dispose of clearants to the sewer system should be considered only after having evaluated all other reuse and disposal choices. Disposal to the sewer system should follow the City's Sewer Use And Wastewater Control Ordinance which specifically prohibits the discharge of pollutants that could create a fire or explosion hazard and limits petroleum oils to a maximum of 100 mg/L. Prior to disposing of clearants the Material Safety Data Sheet, the City's Pollution Prevention program, and the manufacturer can all provide information on choosing the proper disposal method. Most clearants including xylene, limonene, and aliphatic hydrocarbons are flammable and are not water miscible and disposal to the sewer is prohibited. Xylene is flammable (flash point below 100 F), aliphatic hydrocarbons may be flammable or combustible (flash point at or above 100 F), and limonene is combustible.

Fuel Blending: Waste solvents that are not halogenated such as xylene and alcohols are added to fuel oil and burned in boilers or cement kilns for their energy value. Fuel blending provides a useful reuse of the waste as a fuel and is the preferred alternative to disposal to landfills or incinerators. The other advantages of fuel blending is that it reduces disposal costs and environmental liability. Fuel blending facilities such as cement kilns may also be more accessible than hazardous waste incinerators which may have a waiting list. If hazardous waste solvents are to be burned in an on-site burner the EPA will permit the burner under the Boiler-Industrial-Furnace Rules (40CFR Part 266, Subpart H).

Hazardous Waste Disposal: Xylene and xylene substitutes may be disposed of through the services of a hazardous waste disposal company. Xylene can be burned for its energy value at a licensed off-site fuel blending facility. Xylene is banned except for few exceptions from land disposal by EPA's Land Ban regulations as of August 1990.

Alcohols

General Description:

Alcohol solvents are used in high volumes by biomedical laboratories. Cytology and histology use large amounts of alcohols in the form of ethanol, isopropanol, or a mixture of ethanol, isopropanol and methanol. Processes that use alcohol are fixation, staining and slide preparation.

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Waste Material Identification

Determining the composition of commercial alcohol formulations should be based on referring first to the MSDS sheets from the supplier(s). The three main alcohols used are ethanol, methanol, and isopropanol. Ethanol as a waste material from normal histological use may be contaminated stains, organic tissue, water and methanol (Reinhardt, 1996, p. 347).

RCRA Hazardous or non-hazardous? - Hazardous. Due to:

1. Ignitable with a flash point below 140 F. EPA hazardous waste number for ignitability is D001.
2. Methanol from spills, residues, and unused product is a listed toxic waste. EPA hazardous waste number is U154.

Required Action: Handle this waste as a hazardous waste observing all hazardous waste regulations.

REMEMBER: One Pound of Hazardous Waste + 49 Pounds of Nonhazardous Wastes = 50 Pounds of Hazardous Waste

The hierarchy of waste management alternatives for alcohols is as follows:

- Source Reduction: minimize volume of alcohols used
- On-Site Recycling: use an on-site distillation unit to recycle waste alcohol to reuse product
- Disposal: use the services of an EPA licensed hazardous waste disposal company that will preferably burn this waste as a fuel supplement

Alcohol Recycling

Alcohols can be recycled using fractional distillation units. Please refer to the section on distillation in this reference manual for further information. The alcohol solutions that are recommended for recycling are alcohol from processing and alcohol from the last part of the staining setup. It is recommended that alcohol from the purge cycle or from the first part of the staining setup NOT be recycled (Dapson, 1995, p. 143).

Advantages

Reuse of a waste product which eliminates your hazardous waste liability associated with drain or off-site disposal.

There may be economic incentive depending on quantity used.

Disadvantages

Purity requirements. Recycled alcohol will contain water. Alcohol forms an azeotrope with water so there is a ceiling to the highest quality achievable for ethanol (95%) and isopropanol (88%).

Not all alcohol can be recycled. Alcohol with clearing agent should NOT be recycled since the clearing agent will also form an azeotrope with the alcohol resulting in a distilled product contaminated with clearing agent (Dapson, 1995, p. 143).

Disposal

Fuel Supplement Burning: Because alcohols have BTU value (energy value) they can be burned as a fuel supplement at an EPA licensed burner. Refer to the section on fuel supplement burning in this Code for further information.

Hazardous Waste Disposal: A hazardous waste disposal company might dispose of it to an incinerator or as a fuel supplement. Ignitable wastes (EPA # D001) and methanol (EPA # U154) were prohibited from land disposal on August 8, 1990 by the EPA "Land Ban Wastes" regulations.

Drain disposal: This is the least preferable alternative. Small quantities of ethanol, methanol, and isopropanol may be disposed of to the sewer provided they are dilute enough to not pose a fire hazard. These alcohols are flammable in concentrated form but they are also water soluble which will reduce their flammability.

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Metals and Inorganics

General Description

Metals such as copper, silver, mercury, zinc and chromium are ingredients of the chemicals used in some reagents. The disposal of metal bearing reagents should be minimized to reduce the amount of metals the Southside Water Reclamation Plant receives. Metals are not destroyed in the treatment process and end up either as sludge or in the treatment plant effluent discharged to the Rio Grande river. The treatment plant must meet strict limits for silver and for toxicity testing of the plant's effluent. Biomedical laboratories should prevent the discharge of metals in chemicals that exceed the sewer use ordinance.

There are several alternatives available to pouring metal reagents down the drain. These include treatment, recycling and disposal. The method that carries the greatest environmental benefit is to send the metal waste for reclamation of the metal. On-site treatment is another possible alternative and consists of removing metals sufficiently to allow discharging solutions to the wastewater treatment. The most commonly cited on-site treatment involves precipitating metals as chlorides or hydroxides, allowing the metal precipitate to settle, and decanting the liquid down the drain. Other methods that have been cited in the literature include adding resins which attach to the metal and are filtered and removed. Disposal involves containing the metal solution for disposal as a hazardous waste by a licensed waste hauler.

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Cyanides	4.29
Mercury - see section on mercury	

Tables:	
Table 1 - Limits for Metal Wastes	4.25

Waste Material Identification

Determine the concentration of metal in the chemical solution based on MSDS sheets and/or supplier information. If the concentration is given in percentage, multiply the percentage by an order of magnitude of four (multiply by 10,000) which will result in parts per million (ppm).

$$1\% = 10,000 \text{ ppm}$$

First determine if the metal concentration makes it a hazardous waste by comparing it to EPA's hazardous waste limits for characteristic wastes (see Table 1). If the waste is a liquid then the limits below can be directly applied. If the waste is in the form of a solid or in two phases, then a laboratory analysis test that leaches the material may need to be conducted (a TCLP test). If the limits in Table 1 are exceeded then the waste is hazardous and needs to be handled, stored and disposed of in accordance with hazardous waste regulations.

Other waste characteristics such as corrosivity, reactivity and flammability that may classify waste as hazardous need to be checked. Please refer to Appendix D for more information on what makes a waste hazardous.

The maximum permissible limits for discharge of metals into the sewer are listed in Table 1. Discharging solutions with high metal concentrations to the sewer could cause your facility to exceed the sewer use limits and increase your facility's environmental liability and impact on the environment. Metals discharged to the sewer are only partially removed in the wastewater treatment process and a portion gets discharged into the Rio Grande. Remember, the only place to keep metals from getting into the sewer is at the source!

Required Action: Carefully dispose (or preferably recycle) metal bearing wastes in accordance with sewer use and hazardous waste limits.

REMEMBER: One pound of Hazardous Waste + 49 Pounds of Nonhazardous Waste = 50 Pounds of HAZARDOUS Waste

The hierarchy of waste management alternatives for metals is as follows:

- Source Reduction: Minimize metal bearing reagents use and use non-metal substitutes whenever possible.
- Treatment: Chemical treatment of metal bearing wastes prior to sewerage if feasible. Metal precipitates should be carefully handled and stored and disposed of preferably to a metal reclamation company.
- Disposal: If the concentration of metals exceeds EPA limits then the waste should be handled and disposed of as a hazardous waste. Have metal bearing wastes sent to a reclamation company whenever feasible. Carefully review sewer limits when using it for disposal.

Table 1 - Limits for Metal Wastes

Substance	City of Albuquerque Wastewater Ordinance (mg/L) for Grab Sample	EPA Waste Number ¹	EPA (TCLP) Regulated Level (mg/L)¹
Arsenic	0.051	D004	5.0
Cadmium	0.05	D006	1.0
Chromium (Total)	4.1	D007	5.0
Copper	5.3	None	None
Cyanide	0.45	None ²	None ²
Fluoride	36	None	None
Lead	1.0	5.0	D008
Mercury	0.004	0.2	D009
Molybdenum	0.25	None	None
Nickel	2.0	None	None
Selenium	0.04	D010	1.0
Silver	5	5.0	D011
Zinc	2.2	None	None

¹ Taken from the Code of Federal Regulations (40 CFR 261.24) Toxicity Characteristic Leaching Procedure (TCLP) hazardous waste limits.

² Soluble cyanide salts are acute hazardous wastes (40 CFR 261.33)

Silver

Silver may be precipitated as the highly insoluble silver chloride or silver hydroxide compound. The precipitate should be handled as a hazardous waste or tested using the toxicity leaching test procedure (TCLP) for silver; or preferably sent to a recycler for reclamation of the silver. The solution can be placed in the sewer if there are no other hazardous chemicals remaining. All appropriate safety procedures should be closely followed in any chemical treatment of wastes.

The preferred alternative to disposal of silver precipitate as a hazardous waste is to send it to a metal recycler. Please refer to Appendix C for a list of silver and metal recyclers.

Hydroxide Precipitation

Raise the pH to 9.0 or higher with 1 M sodium hydroxide. Neutralize and discard the fluid down the drain if other ingredients permit. Separate the liquid by decantation or filtration and collect the precipitate (hydroxide of silver) for disposal by a licensed waste hauler or precious metal recoverer. This procedure may not work with ammoniacal silver solutions, whose pH is already above 9.0. Labs using a large amount of silver might invest in a silver recovery unit (Dapson, 1995, p. 213).

Chloride Precipitation

Silver can be removed from silver nitrate waste solutions by adding hydrochloric acid. The supernatant is sewered and the silver chloride precipitate is air dried in a chemical fume hood (Reinhardt, 1996, p. 154).

Uranyl Nitrate

Uranyl Nitrate is used in small quantities in silver stains and acts as a “sensitizer”. It is an irritant (corrosive), highly toxic, a radiation hazard from inhalation of fine particles. It’s radioactivity is blocked by nearly all materials (glass, gloves, and clothes). Extreme care is required when handling the powder and work should be conducted in a fume hood. The histological solutions are usually safer to handle. Uranyl nitrate should be managed and disposed of through the services of a hazardous waste company (Dapson, 1995, p. 218).

The uranyl nitrate is considered source material by definition. Source material is uranium or thorium, or any combination thereof, in any physical or chemical form. If the source material is by weight less than 0.05 percent of the mixture then it is an exempt quantity. Therefore no radioactive materials license and no special waste management techniques are required to address radiological characteristics (from federal regulations - 10CFR20).

A possible substitute to the use of uranyl nitrate is zinc formalin. A recent journal article (Journal of Histotechnology, 1996, V. 19:135-138) detailed the use of zinc formalin as a satisfactory substitute (Dapson, 1996).

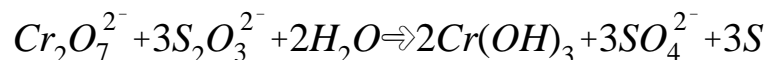
Chromium

Chromium is present in chromic acid (chromium trioxide). Chromium can be precipitated as the insoluble chromium hydroxide and the solution poured down the drain. The chromium precipitate should be handled and disposed of by a hazardous waste hauler. Otherwise, the solid precipitate will require testing it for chromium using the toxicity characteristic leaching procedure test for hazardous wastes determinations.

Hydroxide Precipitation

The following is an excerpt (from Reinhardt, 1996, pp. 287-288):

Insoluble chromium hydroxide is formed by reduction of the dichromate with sodium thiosulfate solution. The efficiency of the reduction and the formation of the product as an easily handled flocculent precipitate rather than as a gel is dependent upon the pH of the solution. For this reason, the solution is first neutralized, then reacidified with a measured volume of acid.



The method is illustrated for a specific quantity of acidic dichromate solution. To ensure complete precipitation of the chromium ions in an easily filterable form, the pH must be carefully adjusted. Thus, to acidic dichromate solution (100 ml) is added solid soda ash slowly and with stirring until the solution is neutral to litmus. About 108 g of soda ash will be required. The color of the solution changes from orange to green. It is reacidified to pH 1 by the careful addition of 55 ml of 3 M sulfuric acid. The color of the solution returns to orange. Alternatively, if it is possible to measure the pH of the solution reasonably accurately, dilute (about 5%) sodium hydroxide can be added slowly to the original acidic dichromate solution to bring it to pH 1. While swirling, sodium thiosulfate (40 g of $Na_2S_2O_3 \cdot 5H_2O$) is added. The solution becomes blue colored and cloudy and it is neutralized by the addition of soda ash (10g). After a few minutes, a blue-gray flocculent precipitate forms. The mixture can be filtered immediately through Celite or allowed to stand for 1 week, when much of the supernatant liquid can be decanted. In the latter case, the remaining liquid is allowed to evaporate or be filtered through Celite. Analysis by atomic absorption spectroscopy showed that the supernatant liquid contains less than 0.5 ppm of chromium. Most local regulations allow this solution to be washed into the drain. The solid residue should be packaged and labeled for appropriate disposal depending on local regulations. Aqueous solutions of other chromium salts such as chromium trioxide can be treated similarly.

Cyanide

Hematology laboratories may use cell lysing solutions that contain cyanide in the form of

potassium cyanide. Aqueous solutions of potassium or sodium cyanide are highly toxic and should be carefully managed and disposed of. Other forms of cyanide found in laboratories such as in histology and pathology include potassium ferricyanide and potassium ferrocyanide which have a low toxicity as long as they aren't heated (Dapson 1995, p. 211). The management alternatives are listed below in order of preference:

1. Material Substitution: Use non-cyanide cell lysing solutions in place of the cyanide containing products. One successful substitution uses a replacement (sodium lauryl sulfate) in automated hemoglobin tests.
2. Disposal: Dispose of cyanide bearing solutions using the services of a licensed hazardous waste hauler. Do not discharge cyanide solutions containing more than .45 mg/l of total cyanide down the sewer.

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Mercury

General Description

Mercury is naturally occurring in nature and is an element present in soil, water, air and living organisms. Mercury is naturally released into the atmosphere through volcanic eruptions and the burning of fossil fuels. Mercury is found to settle on land, rivers, and lakes. Three major chemical forms of mercury are circulated in the atmosphere. These are metallic mercury, inorganic mercury salts, and organic mercury compounds. Methylmercury is the organic form of mercury and is less common than the other two forms but is the most dangerous form in the environment. Methylmercury is the only chemical form that bioaccumulates in muscle tissue of animals.

Although mercury is omnipresent in small concentrations, it is highly toxic to people and to the environment at higher concentrations. Short term exposure to high concentrations of mercury can cause poisoning, pneumonitis, bronchitis, and bronchiolitis. Long term exposures to lower concentrations may cause muscle tremors, irritability, personality changes, or gingivitis. Mercury can also cause damage to prenatal life. (Terrene Institute, Case Against Hg). Spilled liquid mercury can volatilize especially if heated and is odorless and colorless. Even though mercury is used safely in biomedical applications, the goal is to reduce or eliminate mercury at the source before it can be release into the environment through the sewers, landfill, or burning of waste.

Mercury is found as a solid, liquid, or gas. At room temperature, pure mercury is a liquid such as is found in thermometers. Applications of mercury are numerous. Mercury is present in medical facilities in many different applications such as batteries, thermometers, lamps, and electrical equipment. Mercury has historically been used in several chemicals used for fixation and staining in the biomedical laboratory. There are available alternatives for fixatives, stains, and thermometers that use no mercury. Remember, any mercury released into the environment can be converted to methyl mercury which bioaccumulates in the environment.

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Waste Material Identification

Mercury may be present in fixatives, stains and chemicals that biomedical laboratories stock. The following compounds used in biomedical laboratories contain mercury (From PAR p. 158):

Table 1 - Laboratory Chemicals That Contain Mercury

B-5 (mercuric chloride)
Helly's (mercuric salts)
Zenkers (mercuric salts)
Mercuric bichloride/acetic acid
Mercuric chloride
Mercuric oxide
Mercuric bromide
Hematoxylin Stain (Harris)
Thimerosal
Mercurochrome (merbromin)

Hazardous or non-hazardous? - Hazardous, due to:

1. Waste mixtures that are generated from mercury containing products are subject to toxicity characteristic (TCLP) testing for mercury. The waste is hazardous (EPA # D009) if the concentration of mercury exceeds 0.2 mg/L of mercury.
2. Product spill residues, container residues, and unused or new product that become waste are classified as a hazardous waste (EPA hazardous waste numbers D009 and U151).

REMEMBER: One Pound of Hazardous Waste + 49 Pounds of Nonhazardous Wastes = 50 Pounds of Hazardous Waste

The hierarchy of waste management alternatives for mercury wastes is the following:

- Source Reduction: Minimize or substitute mercury in your workplace whenever possible.
- Recycling: Send any mercury bearing waste to a mercury recycler. See Appendix C for a list of mercury recyclers.
- Treatment: Precipitate mercury down to concentrations that can be sewered (see Appendix F) and send precipitate to a mercury recycler (see Appendix C).
- Disposal: Handle and dispose of all mercury wastes as hazardous wastes if mercury concentration is in excess of hazardous waste limits.
- Disposal: Do not sewer mercury bearing wastes.

Mercury salts are present in B-5, Helly's, and Zenker's fixatives. Mercury is highly toxic to the environment and the EPA has ranked mercury as the number one persistent, bioaccumulative and toxic (PBT) metal out of 19 "high hazard" metals. Mercury is a great starting point to target for waste reduction efforts in your laboratory. The following excerpt (from Dapson, 1995, p. 131):

“To better understand the real problem, let’s follow a specimen through from fixation to staining. During fixation, soluble mercuric salts diffuse through the tissue; some attach to tissue sites. Once fixed, the specimen usually is placed into regular formalin, where the unattached mercuric ions diffuse back out of the tissue into the formalin. An equilibrium is reached in time, such that some free mercuric ions remain in the specimen. These in turn diffuse out in subsequent processing fluids, most notably the second and/or third station of fixative. Whether any gets into the lower alcohols at first is not known, but certainly as additional runs of the processor are made without changing solutions, mercury works its way up, contaminating additional stations. All this while, insoluble mercury compounds are forming within the specimen.

Mercury fixatives can be replaced with satisfactory non-mercury alternatives that are commercially available (see Table 2). There are processing differences between the alternatives and conventional mercury fixatives. Biomedical laboratories make use of B-5 fixatives because they produce quick and aggressive results. The non-mercury alternative fixatives require more time to do the job. Four or more hours is recommended for small biopsies and up to eight hours for general surgical specimens (Dapson, 1995, p. 132). Recent experimental data has shown that *Prefer* (ANATECH) and Alcoholic Z-Fix (ANATECH) produce highly satisfactory results (relative to B-5) after only 2 hours for needle biopsies, and 4-6 hours for 4 mm thick surgical specimens (Dapson, 1996).

Table 2 - Suppliers of Mercury Free Fixatives

Product	Supplier	Phone Number
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<i>Prefer</i>	ANATECH 1020 Harts Lake Road Battle Creek, MI	1-800-262-8324
ZINC FORMALIN	ANATECH 1020 Harts Lake Road Battle Creek, MI	1-800-262-8324
ZINC FORMAL-FIX	Shandon Lipshaw 171 Industry Drive Pittsburgh, PA 15275	1-800-245-6212
Z-FIX Alcoholic Z-Fix	ANATECH 1020 Harts Lake Road Battle Creek, MI	1-800-262-8324

Mercury Stains - Alternatives

Harris hematoxylin used in laboratories traditionally has contained mercury. Mercuric oxide acts like an oxidizing agent when added to hematoxylin. Sodium iodate is an alternative oxidizing agent that can be added to eliminate the use of mercury. Most vendors of laboratory chemicals now offer non-mercury hematoxylin solutions.

B-5 or other mercury fixatives are used before the stain as a mordant in some staining programs. A 1% zinc chloride solution heated to 60 F generally can be used as mordant instead of the mercury based mordants (Dapson, 1995, p. 132).

At minimum, mercury hematoxylin should not be mixed with nonmercury hematoxylin. All mercury hematoxylin should be disposed of as hazardous waste.

REMEMBER: One Pound Hazardous + 49 Pounds Nonhazardous = 50 Pounds HAZARDOUS

Substituting Mercury in Chemistry Tests

Ion-Selective electrodes have been substituted to replace the use of mercury solutions (i.e. mercuric nitrate) for the determination of chlorides in body. Trichrome stains used in the parasitology laboratory may contain mercuric chloride as a fixative. Cupric sulfate can be substituted for the mercuric chloride (Reinhardt, 1996, p. 176).

Thermometers

Mercury because of its unique chemical and physical properties has historically been used in thermometers and electrical applications. Mercury is the only metal that is a liquid at room temperature and is one of the best metal conductors. Mercury is also used in batteries and fluorescent lamps due to its electrical properties.

The potential for spills of liquid mercury from broken thermometers can be eliminated by using

non-mercury thermometers. Care must also be taken with non-mercury thermometers spills but it eliminates the disposal of mercury bearing wastes. The alternative thermometers are digital, bimetal, stainless steel or contain organic solvent or mineral spirits.

Spills of Elemental Mercury

Mercury spills can be avoided by using non-mercury chemicals and thermometers whenever possible. The following excerpt is taken from (Prudent Practices, 1995, p. 89):

The initial response to a spill of elemental mercury should be to isolate the spill area and begin the cleanup procedure. Those doing the cleanup should wear protective gloves. The cleanup should begin with collecting the droplets. The large droplets can be consolidated by using a scraper or a piece of cardboard, and the pool of mercury removed with a pump or other appropriate equipment. A standard vacuum cleaner should never be used to pick up mercury. If a house vacuum system is used, it can be protected from the mercury by a charcoal filter in a trap. For cleaning up small mercury droplets, a special vacuum pump may be used, or the mercury may be picked up on wet toweling, which consolidates the small droplets to larger pieces, or picked up with a piece of adhesive tape. Commercial mercury spill cleanup sponges and spill control kits are available. The common practice of using sulfur should be discontinued because the practice is ineffective and the resulting waste creates a disposal problem. The mercury should be placed in a thick-wall high-density polyethylene bottle and transferred to a central depository for reclamation. After a mercury spill the exposed work surfaces and floors should be decontaminated by using an appropriate decontamination kit.

Treatment

Mercury can be precipitated from solution as a carbonate, hydroxide or a sulfide. These reactions should be carried out using all appropriate safety measures. Disposal of treated mercury solutions to the sewer should be done only after you are assured that the mercury concentration meets sewer disposal limits. It is recommended the treated solution be tested for mercury initially and anytime treatment procedures are changed to assure that treatment is adequate.

Carbonate or Hydroxide Precipitation of Mercuric Chloride

Raise the pH to 8.0 or higher with sodium carbonate or sodium hydroxide. Save the precipitate of mercury (either carbonate or hydroxide) for disposal through licensed hazardous waste hauler. Alternatively, it is environmentally preferable to send the mercury to a mercury reclamation company. Appendix C has a list of recyclers. The treated solution can be poured down the drain provided other ingredients permit it to be drained (Dapson, 1995, p. 205).

Sulfide Precipitation of Mercury Ions

Sodium or ammonium sulfide can be added to produce mercuric sulfide which is highly water in-soluble. This treatment process can generate hydrogen sulfide which is a highly toxic gas formed from the sulfide salts in the presence of acid. Appropriate precautions should be taken to prevent the inhalation of hydrogen sulfide. The following excerpt is taken from (Reinhardt, 1996, p. 287):

The waste mercury salts are dissolved as far as possible in water (100 ml for each 10 g of waste). The pH of the solution is adjusted to 10 with 10% sodium hydroxide solution. In a fume hood, aqueous sodium sulfide solution (20%) is added with stirring until no further precipitation occurs. To check whether precipitation is complete a small sample of supernatant liquid is withdrawn and a few drops of sodium sulfide solution are added. If a precipitate or cloudiness appears, more sodium sulfide solution is required. After the precipitate has settled, the liquid is removed by decantation or the solid collected by filtration. The liquid is wasted into the drain and the solid packaged and labeled as mercuric sulfide for appropriate disposal. In the U.S., the wastes must be sent to a thermal treatment facility to recover the mercury.

Disposal

Sewer Disposal: Mercury wastes should not be poured down the drain. The City's Sewer Use and Wastewater Control Ordinance has a limit of 0.004 mg/l for mercury which is the lowest limit applied to any of the chemicals listed in the ordinance. Biomedical laboratories should not make a practice of pouring wastewater with any level of mercury down the drain. Mercury is highly toxic and extremely low levels of mercury are tolerable at the wastewater treatment plant. Mercuric salts should never be sewerred.

Mercury Recycling: Mercury in various forms can be recycled. This is the best option from an environmental viewpoint. You can request that mercury may be sent to a reclamation facility using your hazardous waste disposal company or you can send it directly yourself. Documentation that the mercury was received and reclaimed should be obtained to limit your environmental liability. For a list of recyclers please refer to Appendix C.

Hazardous Waste: Dispose of mercury wastes through the services of UNM's Safety, Health, and Environmental Affairs Department at 277-2753. Do not combine mercury bearing wastes with other types of wastes. For example, segregate any mercury based hematoxylin solutions from other types of hematoxylin. Remember, mixing hazardous waste with nonhazardous waste gives you more hazardous waste. Mercury bearing hazardous wastes (EPA # D009) were prohibited from disposal to a landfill in August 1990 under the EPA's Land Ban hazardous waste regulations.

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Acids and Bases & Cleaners

General Description

Biomedical labs clean hundreds to thousands of glassware pieces weekly. Cleaning encompasses a wide variety of purposes such as removing stains, organic chemicals, blood, cell suspensions and nutrient media from glassware and equipment used in the laboratory.

Acids and bases are corrosive materials that require careful handling and disposal. The use of chromic acid by laboratory personnel may be one of the most dangerous laboratory activities. The hazards involved with chromic acid are corrosiveness, mutagenicity, carcinogenicity, and flammability.

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Waste Material Identification

There are a variety of chemicals and commercial cleaners available. Some may be totally non-toxic and biodegradable and others may contain hazardous chemicals. Review of the Material Safety Data Sheets should indicate the chemical components. If not, then the supplier or manufacturer can be contacted to help determine the proper disposal procedures. Hazardous or non-hazardous?

- Unneutralized acids and bases are hazardous waste based on their corrosiveness if their pH is 2 or less or 12.5 or greater. Neutralization to an acceptable pH may render the waste nonhazardous.

- Chromic acid is a listed toxic hazardous waste (EPA Waste number U032).

Required Action: Handle acids and bases carefully and dispose of them as hazardous waste if they contain hazardous levels of metals or other hazardous compounds. Otherwise, neutralize acids and bases to pH between 5 and 11 prior to sewerage.

Do not mix any material with known hazardous wastes with other nonhazardous materials.

REMEMBER: 1 pound Hazardous + 49 pounds Non-hazardous = 50 pounds HAZARDOUS

The hierarchy of waste management options for acids and bases is as follows:

- Source Reduction: Minimize the use of acids and bases whenever possible. Switch to acids with no chromium.
- Treatment: Neutralize acids and bases prior to sewerage. Do not sewer acids with chromium as they are likely hazardous wastes.
- Disposal: Dispose of chromic acid as a hazardous waste if chromium is not precipitated prior to sewerage.

Glassware Cleaning

Some glassware cleaners use dichromates in sulfuric acid which act as a strong oxidizer. Chromium is an EPA listed toxic metal that can cause wastewater violations in your effluent for chromium. Chromium is listed as an EPA toxicity characteristic parameter. If the concentration of chromium is above 5 mg/l then the waste is regulated as a hazardous waste. There are metal-free glassware cleaners that are strong cleaners without the chromium and are commercially available. The following table summarizes the names of some of these alternative cleaners.

Table 1 - Alternative Laboratory Cleaners

Product Name	Product Contact Company	Phone Number
Alconox (lab soap)	Various suppliers	Check your supplier
3M Brand Citrus-Based Natural Cleaner	3M Industrial Tape and Specialties Division St. Paul, MN	1-800-362-3550 Web Site http://www.mmm.com
Zep Products	Zep Manufacturing Company 2827 Girard Blvd., N.E. Albuquerque, NM 87107	(505) 884-2127
No-Chromix	GODAX Laboratories 720-B Erie Ave. Takoma Park, MD 20912	(301) 588-2825
Micro	International Products Corp. P.O. Box 70 Burlington, NJ 08016-0070	(609) 386-8770
Simple Green	Sunshine Makers, Inc. 15922 Pacific Coast Hwy. Huntington Harbour, CA 92649	1-800-228-0709 (310) 795-6000

Acetone

Acetone is an on-going concern for the Southside Water Reclamation Plant. It is present in the treatment plant's influent and effluent to the Rio Grande river. To date, it is not a pollutant of concern under the City's permit to discharge. However, it could potentially become a pollutant of concern if concentrations were to adversely effect the City's effluent biomonitoring results. In 1995, a survey of permitted industries was completed and most hospital laboratories were found to be using acetone.

Acetone is commonly found in laboratories because of it's effective drying properties. Acetone evaporates rapidly and is used to dry glassware, clean machinery and in "fixing" slides. Acetone has been successfully substituted by ethanol in the laboratory for the cleaning of utensils. A case study in the medicinal industry involving laboratory assistants involved the replacement of acetone with ethanol due to exposure problems with acetone. Irritating odor and headaches were cited as the cause to the switch. Ethanol was found to have a much less irritant effect and the employees were satisfied with the substitution (Filshov, 1996, p. 151).

Ethanol should preferably be recycled on-site through distillation or sent off-site as a fuel supplement. Small quantities of ethanol are generally allowed to be sewered as long as sufficient dilution has occurred to eliminate ethanol's flammability hazard. Acetone should not be sewered because it is flammable and is a substance of concern for water quality at the City's treatment plant. If acetone is used it should be disposed of as hazardous waste (preferable as a fuel supplement).

Treatment & Disposal

Acids and bases that exceed the City's Sewer Use and Wastewater Control Ordinance for pH require treatment prior to pouring them down the drain. The Ordinance states that the maximum allowable concentration for wastewater discharges are between a pH of 5.0 to 11.0. If chromic acid or other metal bearing wastes are being neutralized the precipitated metals after neutralization will need to be managed as a hazardous waste. Metal bearing precipitate should be sent to a metal reclaimer whenever feasible or disposed of through a hazardous waste service company. It is preferable to switch to nonmetal acids to avoid this problem.

Waste acids and bases can be collected separately and then used to neutralize each other. This will reduce the amount of raw chemicals used for neutralization. Careful attention should be given to mixing incompatible chemicals such as waste acids and cyanide which will generate toxic fumes. The following guidelines are given for neutralization (Prudent Practices, 1995, p. 160):

- If an acid or base is highly concentrated it is prudent to first dilute it to a concentration below 10% by adding the acid or base to cold water.
- The concentration of neutral salts formed and discharged to the sewer should generally not exceed 1%.

Chromic Acid Precipitation

Chromic acid (chromium trioxide) or dichromate solution may be precipitated to chromium hydroxide prior to sewerage using the following procedure (Dapson, 1995, p. 195):

1. Bring pH of solution down to 1.0 with the addition of sulfuric acid.
2. Add solid sodium thiosulfate until solution turns cloudy and blue.
3. Neutralize with sodium carbonate.
4. Allow mixture to stand overnight and filter off the precipitate.
5. Discard liquid into the sewer if no other hazardous ingredients are present.
6. Dispose of the precipitate through a licensed hazardous waste company.

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Dyes, Stains and Chromogens

General Description

Stains are made up of a dye and a solvent. When considering disposal options for stains look at both the characteristics of the dye and the solvent. Solvents alone may be considered hazardous due to ignitability and toxicity. There are hundreds of dyes and their toxicological properties are not fully understood in many cases. One of the major problems with handling dyes is their ability to become airborne dusts and become ingested or inhaled.

Picric acid is used in fixatives and in staining. Picric acid is a severe explosion hazard when shocked or exposed to heat or when complexed with metals. Picric acid waste must be stored very carefully and may result in emergency removal by response teams. Instead of using picric acid in fixatives or mordants, the mercuric substitute fixatives should provide the same results. For quicker results, one of the alcoholic B-5 mercuric fixative alternatives can be used.

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Material Identification

Hazardous or non-hazardous? Refer to the MSDS for the product and consult with the distributor or manufacturer for more information about disposal of the product.

- Stains may be hazardous waste due to the solvent used. Solvent may be hazardous due to low flash point (less than 140 F) or may be a listed hazardous waste such as methanol (EPA waste number F003)

- The EPA does not have any hazardous waste numbers for dyes.

Required Action: If hazardous dispose of in accordance with hazardous waste regulations.

Remember: 1 Pound of Hazardous Waste + 49 Pounds of Hazardous Waste = 50 Pounds of HAZARDOUS Waste

The waste management hierarchy for management of dyes and stains is the following:

- Source Reduction: Minimize the volumes used to the extent possible. Substitute less hazardous dyes for hazardous ones whenever feasible.
- Treatment: Some dyes and stains may be detoxified and subsequently sewered.
- Disposal: Dispose of dyes and stains that are hazardous through a licensed hazardous waste disposal company.

Spill Procedure for Dyes

Spills of dye material may become airborne and become inhaled or ingested. Careful cleanup of spilled dyes is required. There are three main types of dyes and this determines how the dyes are cleaned up. The following cleanup procedure is taken from (Dapson, 1995, p. 222):

Acid Dyes (anionic, negatively charged): For very small quantities, don appropriate gloves and wipe contaminated area with a sponge dampened with very dilute ammonia water (ammonium hydroxide). Rinse sponge in a bucket of water, then re-dampen in ammonia water to continue cleaning. A final wash with household bleach or one of the commercial stain removers should clean the area. Pour enough bleach into the bucket of colored water to destroy the staining properties of the dye, before pouring the liquid down the drain.

Basic dyes (cationic, positively charged): For very small quantities, don appropriate gloves and wipe the contaminated area with a sponge dampened with dilute aqueous acetic acid (<5%). Rinse sponge in a bucket of water, then re-dampen in dilute acetic acid to continue cleaning. A final wash with household bleach or one of the commercial stain removers should clean the area. Pour enough bleach into the bucket of colored water to destroy the staining properties of the dye, before pouring the liquid down the drain.

Oil-soluble dyes: For very small quantities, don appropriate gloves and wipe the contaminated area with a previously dry towel dampened with anhydrous alcohol (a sponge usually does not work well here). Rinse the towel in a bucket containing a small quantity of alcohol, and continue cleaning the contaminated area. Repeat with fresh cloths until the area is clean. For some oil-soluble dyes, alcohol will not be sufficient to clean the spill; in these cases, use an aliphatic hydrocarbon clearing agent (do not use xylene; it is much too toxic for this purpose). Collect all colored solvent for proper disposal; do not discard it down the drain. Towels wet with alcohol are flammable (combustible if the appropriate aliphatic hydrocarbon clearant is used); treat these carefully (wring dry, seal in a plastic bag and incinerate).

Picric Acid in Stains

Picric acid is explosive when dry, shocked or heated or comes into contact with metals or metallic salts. It is toxic by skin absorption and its use should be avoided as much as possible. A metal-capped container of picric acid should not be opened due to reactivity hazards. If picric acid is dry do not attempt to handle the container.

A professional hazardous materials response team should be called. Picric acid solutions should never be heated or microwaved. Solutions of picric acid should not be mixed with mercury or zinc salts. Leaching picric acid from specimens into a processor may pose an explosion hazard if metal picrates are formed.

Picric acid is commonly used in stains as an intense yellow counterstain and can be substituted with 0.1-1.9% tartrazine (C.I. #19140) in water with pH < 4.0 (Dapson 1996, p.

132).

Disposal Options

The following guidelines are given to help you make a decision on how to dispose of dyes, stains and chromogens. After reviewing the following guidelines, you will need to decide on one of three disposal options:

- Discharge it untreated into the sewer system
- Detoxify then discharge into the sewer system
- Collect and use a hazardous waste hauler

Guidelines for discharging stains to the sewer system:

- Review the product MSDS sheets and/or contact the manufacturer for ingredients information
- Determine if there are toxic organics (i.e. carcinogenic, mutagenic) or metals present in the stain or dye
- Avoid discharging stains that contain metals and toxic organics over the City's Sewer Use and Wastewater Control Ordinance limits (see Appendix F)
- Don't discharge stains that contain flammable solvents, save these for hazardous waste disposal with other solvents for fuel burning or incineration. Aqueous based dyes may be more expensive to dispose of since they contain small calorific values.
- Ok to discharge dyes due solely to their color.
- Discharge solutions with pH's between 5 and 11
- Prefer to discharge only water based stains
- If you don't have sufficient information to make a good decision, when in doubt deal with it as a hazardous waste.
- If you have any questions, please contact the Pollution Prevention Program at (505) 873-7004.

Guidelines for pretreatment of solutions before discharging them to the sewer:

- Don't attempt a detoxification unless you know it works
- Adding chlorine may create toxic chlorinated derivatives
- Do not detoxify the chromogens AEC (Aminoethylcarbazole) and DAB (diaminobenzidine tetrahydrochloride) with chlorine bleach (sodium hypochlorite) because the products remain toxic. There are two methods to detoxify DAB. One method is described as follows (from Dapson, 1995, p. 162):

DAB detoxification procedure

1. Prepare the following aqueous stock solutions
 - a. 0.2 M potassium permanganate (31.6 g KMnO_4 /liter)
 - b. 2.0 M sulfuric acid (112 ml concentrated acid/liter)
2. Dilute the DAB solution if necessary so that its concentration does not exceed 0.9 mg/ml.
3. For each 10 ml of DAB solution, add:
 - a. 5 ml 0.2 M potassium permanganate
 - b. 5 ml 2.0 M sulfuric acid

4. Allow mixture to stand for at least 10 hours. It is now non-mutagenic.

Stain waste guidelines when storing and using a hazardous waste hauler:

- If the stain contains flammable solvents, be sure to store it as a flammable waste.
- The following dyes are considered carcinogenic and should be disposed of by UNM's Safety, Health and Environmental Affairs Department by calling 277-2753: auramine O (CI 41000); basic fuchsin (pararosaniline hydrochloride, CI 42500); chlorazol black E (CI 30235); ponceau 2R (ponceau de xylidine, CI 16150).

Distillation

General Description

There are commercially available distillation units that will recycle fixatives, clearants, alcohols, and solvents to laboratory grade. Instead of disposing of quantities of these spent materials, they can be recycled multiple times. Distillation offers many advantages to laboratories to implement pollution prevention. Distillation in many cases is highly cost effective. Distillation reduces the amount of waste generated and the generators' liability for the fate of their waste chemicals. This section contains information about how distillation works, which materials can be distilled with the available technologies. An economic feasibility worksheet is also included to evaluate your recycling opportunities.

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Distillation of Liquids

Vapor pressure and boiling points of liquids are important physical and chemical properties of materials to be distilled. A liquid at a given temperature placed in a closed container will reach after some length of time a state of equilibrium between the liquid and gas phases. The vapor pressure of that liquid is defined as the pressure in the air above the liquid inside the container at that temperature. As the temperature of the liquid increases the vapor pressure also increases. At some temperature specific for that material, the vapor pressure exerted by that liquid will equal the atmospheric pressure. When the vapor pressure is equal to the atmospheric pressure that is defined as the boiling point of the liquid.

One atmosphere is a standard unit of pressure equal to the pressure exerted by 760 millimeters of mercury (760 torr). The pressure at sea level is normally about one atmosphere. The table below shows the boiling point of several commonly used laboratory solvents. The atmospheric pressure in Albuquerque is not the standard sea level pressure of 760 torr. Thus the boiling point temperature is reached sooner than at sea level.

Table 1 - Boiling Point of Several Common Laboratory Chemicals

Solvent	Boiling Point At Sea Level (Degrees Fahrenheit)
Formaldehyde (37%)	205
Xylene	279
Ethanol	171
Isopropyl Alcohol	180
Methanol	149
Water	212

Simple Distillation

Simple distillation separates volatile liquids mainly from solids and nonvolatile liquids. It involves heating a material so that compounds will reach their boiling point, becomes a gas, and then the gas condenses as it cools to once again it's liquid state. The basic equipment components used in simple distillation are a pot flask, heating source, a condenser, thermometer and a receiving flask.

Fractional Distillation

When several volatile liquids are mixed together the separation of the mixture into each component becomes more difficult. Each volatile component has a different boiling point and several components may volatilize all at the same time. The basic equipment for fractional distillation consists of a pot flask, heating source, fractionating column, condenser, thermometer

and a receiver flask as is shown below in Figure 1.

Fractional distillation is different from simple distillation because of the use of the fractionating column. The type and characteristics of the column are important and are further discussed below. For example, as a liquid mixture made up of two volatile components A and B is heated, both compounds A and B will volatilize and produce a gas. When the gas is cooled the liquid will contain both compounds A and B.

The fractionating column is designed especially to provide an area where vapor rises and

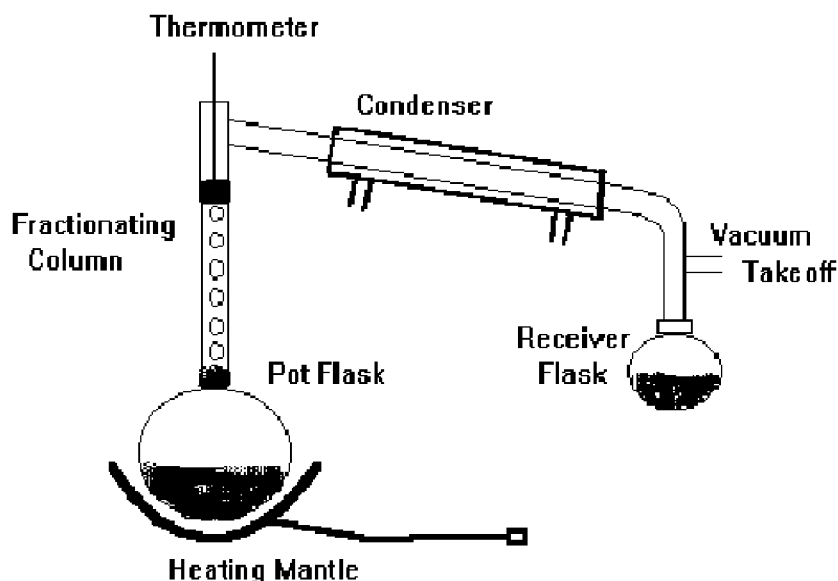


Figure 1 - Fractional Distillation Setup

condenses repeatedly. The gas and liquid continually come into contact with one another. The process of vaporization and condensation occurs inside the column many times. Each time the gas is condensed on the column it completes one simple distillation. The process that occurs within the fractionating column steadily increases the purity of a single component in favor of the other components thereby concentrating the purity of the component. One simple distillation is referred to as one theoretical plate (Reinhardt, 1996, p. 246).

Sometimes a mixture may have what are called azeotropic minimums or maximums. Azeotropic behavior means that there is a point where the vapor and liquid have equal composition of components. Once the azeotropic point is reached it is impossible to further purify the solution into its components. For instance a mixture of ethanol and water has an azeotropic minimum and can be purified to a point of 95% ethanol and 5 % (Brady, 1990, p. 438). Likewise, isopropanol can be distilled to a maximum purity of 88% due to azeotropic behavior.

Characteristics of Stills Commercially Available

Commercially available stills fall into the two broad categories of either simple distillation or fractional distillation. Simple distillation stills are used to purify solvents to a commercial grade

and are generally applicable to mixtures with only one volatile component.

The second type of still available is the fractional still and it's used to distill solvents to laboratory grade. The fractionating column on the still is one of the most important parts of the still. The column will determine the purity and efficiency of recovered solvent(s). There are a variety of fractionating columns commercially available. Some examples of column types available are the spinning band column, stationary element column, plate column, empty tube column, and the packed column.

The operational characteristics of columns are efficiency, holdup, throughput, and pressure drop, and equilibration time. A column with a high efficiency will have a high number of plates (N) and thus a low HETP. Spinning band columns have high efficiencies as reflected by a low HETP (Reinhardt, 1996, pp. 248 to 259).

Efficiency

The efficiency is described in two ways. One is by the theoretical plate denoted by the following symbol: N. One theoretical plate is one fully equilibrated simple distillation. The second way to describe efficiency is by the Height Equivalent to a Theoretical Plate (HETP). The HETP represents the number of plates in a given length of column and is calculated in the following equation:

$$\text{HETP} = (\text{column length in cm}) / \text{Number of plates (N)}$$

Holdup

The material that clings onto the column at any time during the distillation is called holdup. The less holdup the better especially when small volumes are distilled.

Throughput

Throughput is the rate at which vapor passes through the column generally expressed as volume per unit time. Other similar terms are Vapor Velocity and Boilup Rate.

Reflux Ratio

The reflux ratio measures the material withdrawn from the column versus the material allowed to return to the column. It can be controlled by a valve that may be programmed to open and close.

Pressure Drop

The pressure drop refers to the difference in pressure between the pot flask and the distillation head. Flooding occurs on the column when the pressure drop increases so much that condensate on the column no longer falls.

Equilibration Time

The amount of time required for an equilibrium to exist between the falling liquid and rising vapor. Most applications have equilibration times under an hour.

The following table summarizes the characteristics for the five classes of fractional columns mentioned.

Table 2 - Characteristics of Distillation Columns

Column Type	Throughput (milliliters/min ute)	Efficiency (HETP) (cm/plate)	Holdup (ml/plate)
Empty tube (Vigreux)	5-10	7-12	0.5-2
Packed	2-7	3-5	0.7-1
Plate	1-5	1-2	0.2-0.5
Stationary	0.5-2	0.5-3	0.01-0.03
Spinning band	3-20	0.4-3	0.01-0.03

Adapted from (Reinhardt, 1996 p. 260)

The spinning band column is commonly used in biomedical laboratories to distill solvents. The spinning band column has two bands in the shape of a helix that rotate inside the column. Liquid that condenses in the column is forced by the spinning band to form a thin film on the inside walls of the column. As the liquid makes its way down the column, the exposure between liquid and vapor is high which is reflected by the low HETP value as shown in Table 2.

There are separate portions of the distilled liquid referred to as “cuts”. The forecut is obtained at the beginning of the distillation and consists of lower boiling point material. The heartcut is obtained next and is generally the purest form of the distilled material. The pot residue is the material that remains in the distillation flask after the distillation has been completed.

Materials That Can Be Distilled

Many of the fixatives, clearants, alcohols and solvents used by biomedical laboratories can be recycled using distillation. The contaminants that each solvent has will depend on the processes used in the laboratory. A study from over 200 hospital labs found alcohol contamination in used xylene to range from 0.6 to over 64%. The average alcohol contamination in used xylene was found to be 14.9% (Reinhardt, 1996, p. 341). The following table shows a list of some of the possible contaminants of common solvents used in the biomedical laboratory.

Table 3 - Solvent Contaminants Table

Waste Solvent	Process	Potential Contaminants
Formaldehyde	Fixation	Water, dissolved or particulate solids from tissue
Alcohols	Tissue processing	Tissue fat and particles, stain residue, clearing agents, water

Xylene	Tissue processing	Tissue fat and particles, paraffin, alcohol, water
--------	-------------------	--

Adapted from Dapson, 1995, p. 142

Contaminants can form azeotropic mixtures which will limit the highest purity achievable. As was discussed earlier, the alcohol-water mixture reaches an azeotropic point making the purest ethanol obtainable about 95% and the purest isopropanol recoverable at 88%. However, the alcohol-clearant or alcohol-water-clearant mixtures can be a problem when recycling due to the formation of azeotropes. The following tables are a summary of the recommend recyclable and non-recyclable solvents.

Table 4 - Recyclable Solvents

Material	Process
Alcohols	Processing Last part of staining setup
Xylene	Processing Purge Cycle First part of staining setup Last part of staining setup
Xylene Substitutes	Short chain aliphatic hydrocarbons
Formaldehyde	

Adapted from Dapson, 1995, p. 143.

Table 5 - Non-Recyclable Solvents

Material	Process
Alcohols	Purge cycle First part of staining setup
Xylene Substitutes	Long-Chain Aliphatics
Limonene (citrus based) clearants	Clearant

Adapted from Dapson, 1995, p. 143

Economic Feasibility Analysis

Perhaps the most convincing reason to implement pollution prevention opportunities is the economic analysis. An economic feasibility analysis can be used to support pollution prevention opportunities by laboratory managers to upper management. Recycling of solvents makes environmental sense and in many cases is also an economic investment. Recycling of solvents will reduce expenses by reducing raw material purchases, waste disposal and freight charges. Frequently recycling has other nontangible benefits such as compliance with waste disposal regulations and a load reduction of toxic substances to the wastewater treatment plant. The following forms are intended to help you perform an economic analysis of distillation. These worksheets can be used for any solvents being considered for distillation.

Economic Analysis Worksheet
Solvent Recycling By On-Site Distillation

Name of Solvent:	
A. Quantity of Recyclable Solvent Used	gallons/year
NOT RECYCLING COSTS	
B. New Solvent Purchase Costs	\$/gallon
C. Freight Charges for New Solvents	\$/gallon
D. Total Cost of Purchasing New Solvent D = B+C	\$/gallon
E. Solvent Disposal Cost	\$/gallon
F. Total Cost of Not Recycling F = D+E	\$/gallon
G. TOTAL COST of NOT RECYCLING G = F x A	\$/year
RECYCLING - OPERATION & MAINTENANCE COSTS (O & M)	
H. Still Operation - Labor in one year	\$/year
I. Still Maintenance - Labor in one year	\$/year
J. Power Costs in one year J = A x (\$/gallon)	\$/year
K. Water Costs in one year	\$/year
L. Total O & M costs for one year L = H+I+J+K	\$/year
SOLVENT RECONSTITUTION COSTS	
M. Cost of chemicals to reconstitute solvent after recycling (if needed, i.e. for recycling of formaldehyde)	\$/year
STILL BOTTOM COSTS	
N. Still Recovery Rate	%

O. Still Bottom Volume $O = A \times ((100 - N)/100)$	gallons/year
P. Cost of disposing of still bottoms $P = O \times E$	\$/year
Q. Cost of makeup solvent $Q = O \times D$	\$/year
R. TOTAL COST OF STILL BOTTOM $R = P + Q$	\$/year
S. TOTAL COST of RECYCLING $S = L + M + R$	\$/year
T. SAVINGS DIFFERENCE WITH RECYCLING $T = G - S$	\$/year
U. DISTILLATION UNIT COSTS	
V. Capital Cost of Still	\$
W. Still Installation - Materials	\$
X. Still Installation - Labor	\$
Y. Total Capital Cost of Still $Y = V + W + X$	\$
Z. PAYBACK PERIOD FOR RECYCLING $Z = Y/T$	years

Calculations:

A. Quantity of Recyclable Solvent Used = (gallons/day) x (number of working days/year). This number is not necessarily the total quantity of solvent your laboratory uses. Only the solvent that is recyclable (see Table 4 - Recyclable Solvents) should be used in the cost benefit analysis worksheet.

B and C. New Solvent Purchase Costs - refer to your own purchasing records or alternatively, ask your supplier about your purchasing costs.

E. The cost of disposing of your solvent wastes may be difficult to calculate accurately because some waste disposal companies charge flat rate fees for bulk shipments or have complex fee schedules. Be sure to consider all fees such as pickup fees, analytical lab fees, and maybe consulting fees (Dapson, p. 145).

H. Still Operation Labor in one year = (hours/week) x (rate/hr) x 52 weeks/yr. Consult with vendor on the amount of operation labor time required for their product.

I. Still Maintenance Labor in one year = (hours/week) x (rate/hr) x 52 weeks/yr.

J. Power Costs = Vendor should be able to provide the power costs per gallon for distillation.

K. Water Costs can be calculated by finding out how much water will be required to run the still. Refer to vendor for this information.

M. Reconstitution costs refers to any salts or chemicals that may need to be added to reconstitute the chemical composition of the solvent back to it's original form. An example of a solvent that may require reconstitution after distillation is formaldehyde. There are assay and salt kits to reconstitute recycled formaldehyde. Data used in this calculation will include the quantity of solvent used from line A of this table. For example, it may cost \$0.50/gallon of reconstitution salts and then multiply by gallons per year solvent used (see at) to yield \$/year.

N. Still recovery rate is the percentage by volume of product that can be recovered from the total product distilled. Different solvents and stills may have different recovery rates. Check with your vendor for this information.

P. Cost of disposing of still bottoms can be calculated by knowing the cost of disposal for solvent wastes (see Part E).

U. The breakdown of distillation costs should be obtained from your distillation unit vendor.

Questions To Ask Your Vendor

Will on-site recycling yield a useable product?

Which solvents can be distilled?

Can the still be operated safely for my application (i.e. flammability)?

Does the unit have an automatic cleaning cycle?

Is a filter to remove solids recommended prior to distillation?

Is there a concern with odor problems from the unit?

What are the venting requirements for the still?

What is the recovery rate for the solvent distillation?

Will the vendor distill a sample of my waste solvent?

Does the vendor provide a user's manual, operator training and a training manual?

Will the vendor be able to modify, repair, or upgrade the system?

What are the costs breakdown of the still? Make sure to ask for all those maintenance costs listed in the economic analysis worksheet.

Can I easily setup the still myself or will vendor assistance be needed?

What is the normal life of the main components of the still and the frequency of replacement for smaller components?

Regulatory Considerations

Consult with UNM's Safety, Health and Environmental Affairs Department to be sure that all hazards are addressed. The recycled solvent and solvent still bottoms should be managed in accordance with hazardous wastes regulations. The use of on-site recycling reduces the waste volume and can lower your company's generator classification. The State of New Mexico is authorized to enforce hazardous wastes laws including the federal Resource Conservation and Recovery Act (RCRA) laws and the State Hazardous Waste Act (RCRA equivalent). The RCRA regulations cover a wide range of activities associated with hazardous waste generation, treatment, storage, disposal and transportation. For more information on hazardous waste please refer to the Hazardous Waste Information (Appendix D). Refer to the appendix on University, City, State and Federal Environmental Resources for a listing of agencies and phone numbers.

Safety Considerations

Xylene, alcohols and formaldehyde are flammable and toxic materials that require careful consideration for the safe recycling of these materials (from Minnesota Technical Assistance Program).

- Is there a safe location for the still? Be sure to consider fire code requirements, location of sewer drains, sources of ignition, and ventilation requirements.
- Most industrial equipment requires inspection and approval may be facilitated if the entire piece of equipment is approved by an independent laboratory such as the Underwriter's Laboratories or Factory Mutual. The use of approved components is the next best situation. Consider requiring a performance guarantee for the installation and successful inspection from the electrical inspector and fire Marshall.
- Are the following minimum safety features present on the machine that you are considering?
 1. Automatic shut down for high pot temperature to prevent the still bottoms from continuing to cook after all solvent has boiled off.
 2. Automatic shut down for high condenser-water temperature to prevent solvent vapors from being lost due to malfunctions that cause low or no coolant flow.
 3. A relief valve for pressure buildup.
 4. Controls that are explosion-proof, intrinsically safe or installed in a remote location if flammable solvents are processed. Equipment installed in a hazardous location (as defined by the fire code) should be approved by an independent testing laboratory to verify compliance with the National Electrical Code.
 5. Interlock features that prevent opening of the still until it has cooled to a certain temperature.
- How are the solvent vapors condensed?

Water is generally the simplest and least costly cooling medium. Air cooling can make sense in some cases, such as for very small units, but electric fan motors are generally not explosion-proof and their use should be carefully evaluated. Refrigerated chillers are expensive.
- Does your solvent contain explosive substances when dry?

Picric acid is used sometimes as a fixative, mordant, or in stains and is explosive especially when dry, shocked, or heated or in contact with metals or metallic salts (Dapson, 1995, p. 210). There are substitutes for picric acid that are less hazardous materials.

Maintaining Your Still (from Washington State #94-31)

- Keep distillation equipment clean by not allowing tissue components from specimens to build up on the walls of the still to prevent odors and contamination of recycled solvents (Dapson, 1995, p. 143).
- Make sure the distillation unit has the proper temperature range, capacity, and processing time for the solvent you want to recycle.
- Low solids in the material to be distilled will help the still operate efficiently. High solids insulate the heat source from the solvent and reduce the efficiency of the recovery.
- The success of your solvent recycling program may depend on having an individual dedicated to supervising and initiating the operation.

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Solvent Fuel Blending

General Description

Solvents and organic chemicals were initially disposed of in landfills in some form of land dumping. Drums and tanker trucks filled with solvent were acceptable at landfills that could absorb the liquid solvent. After incidents of local groundwater pollution arose and as the more solvent waste increased, solvent disposal sites were more carefully selected such as rock quarries, clay pits, and secure underground mines to minimize environmental impacts. As disposal sites filled up the need for other options developed. There was a tendency to begin dumping or incinerating solvents at sea in areas not used for fishing. Incineration of halogenated solvents produces hydrochloric acid. Incineration at sea was especially attractive because the fumes were neutralized when they contacted the alkaline sea waters. Solvents with volatile organics discharged directly to the sea evaporated from the sea surface adding to the VOCs being discharged to the environment (Smallwood, 1993, p.129).

In the 1990s, the disposal of solvents is more restricted with EPA Land Ban and ocean dumping restrictions. The waste solvents can be burned for their fuel value or incinerated. There are land based incinerators with extensive pollution abatement equipment available for incineration of solvents, organics, and inorganics. Burning waste as a fuel supplement is different than sending it to an incinerator. The preferred option is to send waste for combustion rather than incineration because heat energy is recovered for a useful purpose such as for producing heat energy in a boiler or a cement kiln. The primary purpose of an incinerator is to destroy hazardous waste and not necessarily to recover energy.

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Burning Wastes Off-Site for Energy Value

Solvents that are burned for their energy are burned in cement kilns, for drying road base, or for making steam. Cement kilns operate at many of the required conditions to properly destroy waste solvents. The two basic types of cement manufacturing processes are wet and dry. The wet process uses about twice as much heat as the dry process. Cement manufacturing requires high operating temperatures at about 1500 degrees. In addition, the gases have long residence times of about 30 seconds. Dust from the combustion is removed using electrostatic precipitators which are very effective especially compared to scrubbers. If halogenated organics are present they react quickly to form part of the cement clinker since the conditions are highly alkaline in the kiln. In the United States there are about 30 cement kilns that are equipped to burn waste solvents (Smallwood, 1993, p.129).

Table 1 - Calorific Value of Several Common Laboratory Chemicals

Solvent	Lower Calorific Value (BTU/lb)
Ethanol	11570
Hexane	19246
Acetone	12250
Methanol	8419

Heat available from the combustion of solvents at a concentration of 50% LEL in air: under adiabatic conditions this will raise the air to about 1000F or 550C. (Adopted from Smallwood, 1993, p. 172).

The following table shows the typical specification limits for waste solvents to be burned in a cement kiln.

Table 2 - Typical Specification Limits for Solvent Wastes

Parameter	Specification
Solid particles	3 mm diameter maximum
Heat Content	5000 kcal/kg minimum
Ash	10% maximum
Sulphur	3% maximum
Fluorine	1 % maximum (fluxes kiln lining)
Chlorine and Bromine	4% maximum
pH	5-10
Table 2 - Continued	
Viscosity	100 cP maximum
Lead and Zinc	1000 ppm (stop cement setting)

Chromium, Cadmium, Arsenic, Mercury	200 ppm (toxic)
Carbon tetrachloride	Non Detectable (toxic)
Benzene	Non Detectable (toxic)
Other highly toxic PCBs	50 ppm maximum

Adapted from Smallwood, 1993, p. 132.

Incineration

Waste solvents and organics are sent to thermal hazardous waste incinerators to be destroyed by complete combustion. Thermal incinerators use high combustion temperatures, excess air (30-50%), and adequate residence times. To have adequate combustion of organics, a minimum temperature of 1100 degrees Celsius and a residence time of 4 seconds is used in the high-temperature zone of the incinerator. In order to achieve the proper incineration temperature, wastes need to have a minimum calorific value of about 5000 kcal/kg which is equal to 9000 BTU/lb. The lack of organics with calorific value will reduce the overall calorific value of the waste and may require additional support fuel for proper combustion. Water in a waste mixture does not have as much of an effect on the calorific value as does the absence of solvent with a sufficient calorific value. (Smallwood, 1993, p. 130). Hazardous waste disposal companies may charge extra when there is water present or when the calorific value of the waste is low.

Incinerators must meet air standards for the discharge of their effluent air. Incinerators may need to scrub out acids produced, particularly when combusting halogenated organics that produce hydrochloric acid. If inorganics are being burned then incinerators need to be equipped to remove dust from the effluent.